Opportunities for Detector-Free Signal Offset Optimization with Limited Connected Vehicle Market Penetration: A Proof-of-Concept Study

Christopher M. Day and Darcy M. Bullock

Paper No. 16-0112

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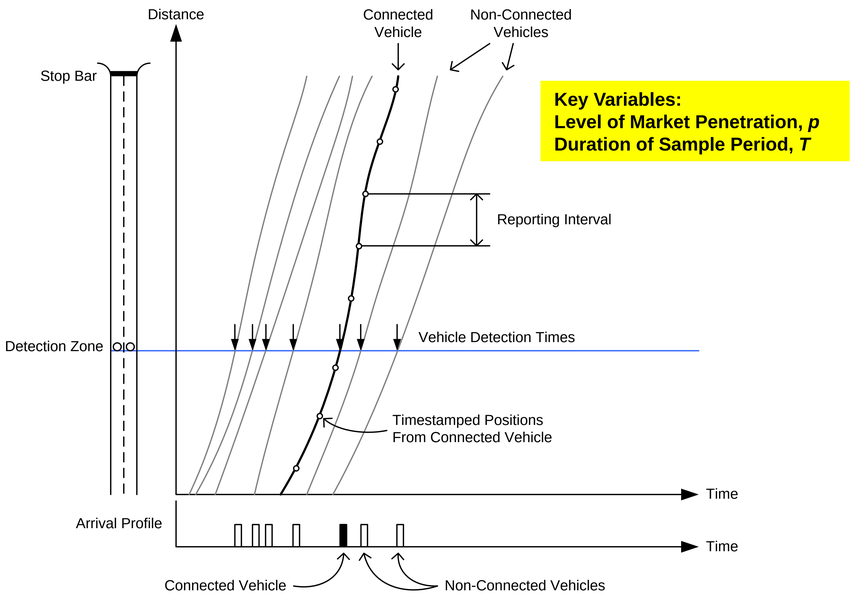
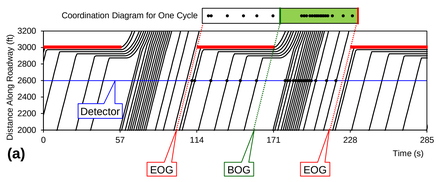
CONNECTED VEHICLE CONCEPTS

Connected Vehicle Equivalents to Detector Data

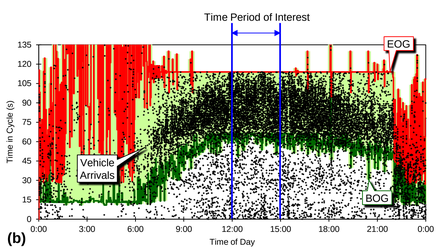


MEASURING VEHICLE ARRIVALS

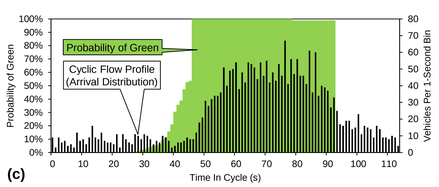
Actual Vehicle Arrivals
- The trajectory view contains all the relevant information
- Arrival times measured by a setback detector
- Phase times measured by the local controller



Purdue Coordination Diagram
- Originally described by Day et al. (2009), (DOI: 10.3141/2192-04)
- Shows individual vehicle arrivals in relation to the duration of green
- Visualize arrival characteristics for various times of day in a single graphical representation

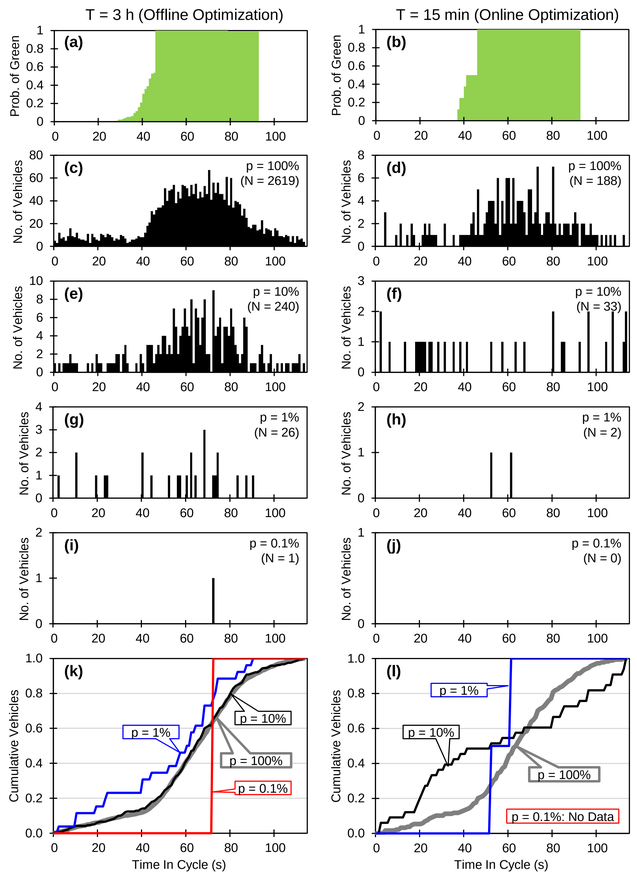


Cyclic Flow Profile
- Introduced in the 1960s as core component of TRANSYT
- Shows average cyclic distribution over a time period
- Useful for optimization

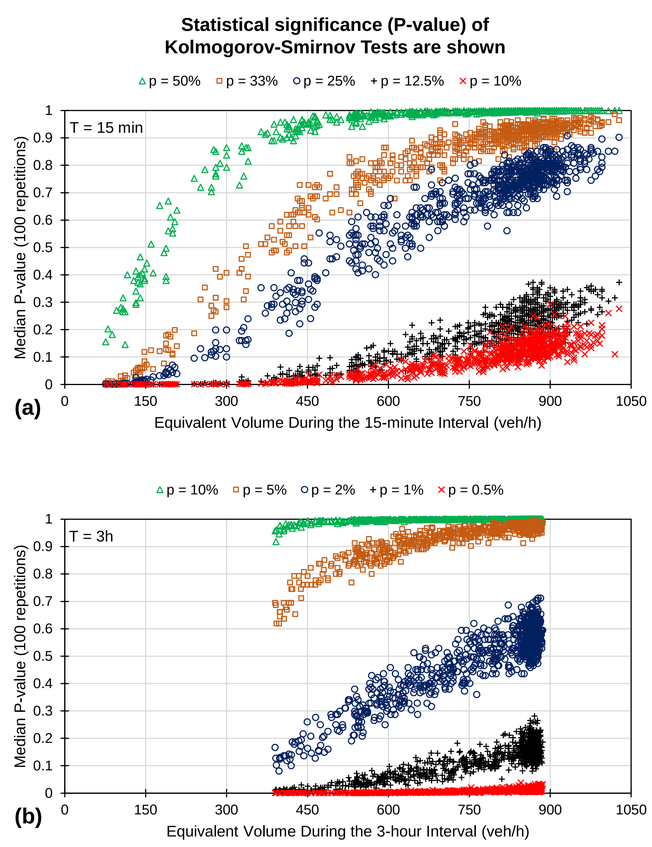


SAMPLING METHODOLOGY OVERVIEW

Taking Subsets of the Detector Data as Example Connected Vehicle Arrival Data



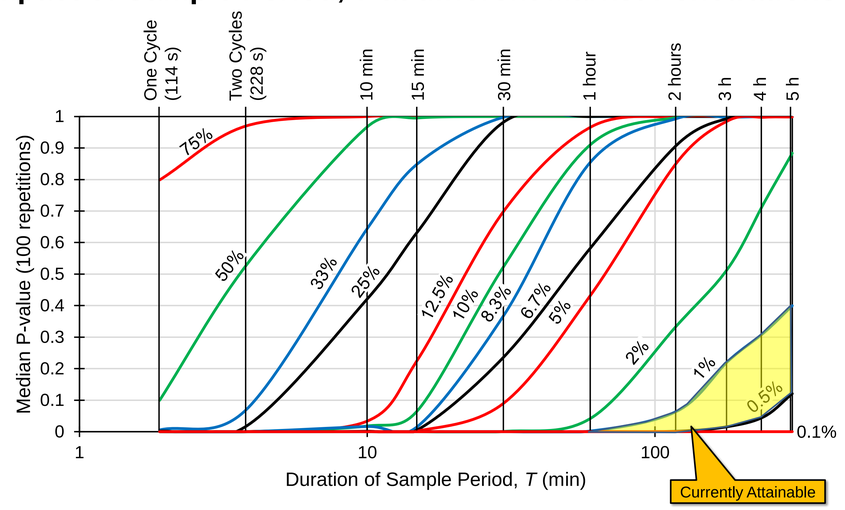
Impact of Volume on Accuracy of Subset Profiles at Different Values of Market Penetration *P*



Methodology Overview

- Complete data from measured arrivals was subsampled to develop example Connected Vehicle data for different market penetrations
- Impact of sample period investigated
  - T = 15 minutes used for “online” optimization
  - T = 3 hours used for “offline” optimization
- 100 different iterations carried out for each market penetration level and sample period
- Performance of sampled distributions for offset optimization compared by using the resulting settings into the complete-data model

Impact of Sample Period, *T* at different Market Penetrations



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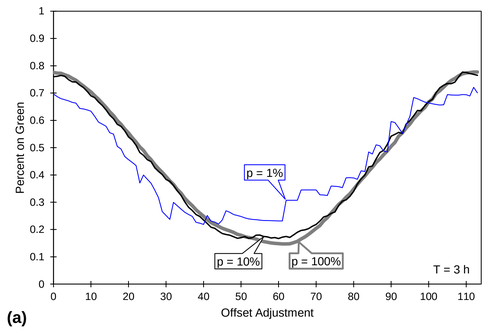
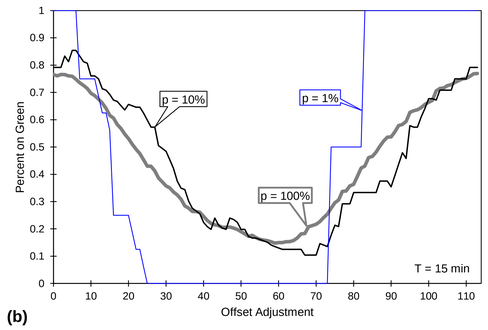
OFFSET-PERFORMANCE CURVES FOR DIFFERENT MARKET PENETRATIONS

Offline Optimization
- T = 3 Hours
- Curves are very similar even for p = 1%
- Opportunity at low levels of market penetration



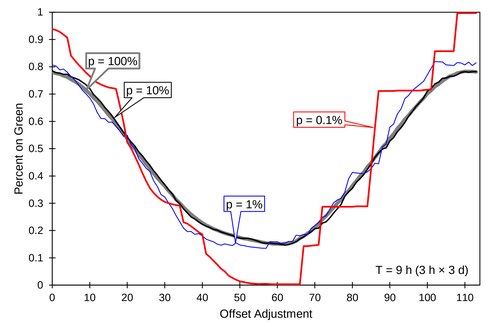
(a)

Online Optimization
- T = 15 Minutes
- Curves are very similar for p = 10%
- The p = 1% curve is not very accurate
- Opportunity at moderate levels of market penetration



(b)

Extended Offline Optimization
- T = 9 Hours (3 Hours over Three Days)
- Curves are very similar even for p = 0.1%
- Opportunity at very low levels of market penetration

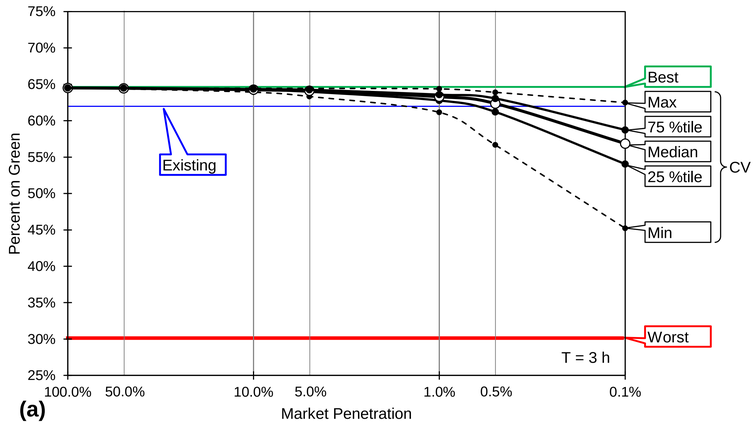


OVERVIEW OF RESULTS

- Solution quality varied with market penetration as expected.
- Opportunities for detector-free offset optimization exist at relatively low levels of market penetration
  - For “online” optimization (T = 15 min), p = 5% may be viable
  - For “offline” optimization (T = 3 hr), p = 1% may be viable
  - Layering multiple days of data might make even lower rates viable
- Some example real-world data shown in poster. The equivalent level of penetration is approximately 0.6–0.8%.
- Primary barrier to implementation will likely be time synchronization between data sets.

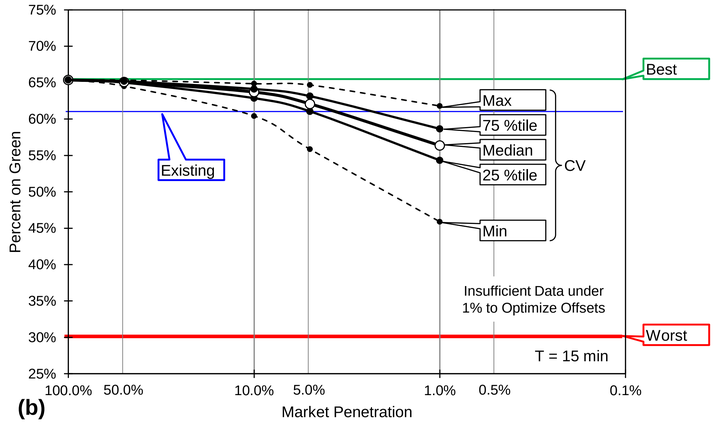
SENSITIVITY OF OFFSET OPTIMIZATION OUTCOMES TO MARKET PENETRATION RATE

Offline Optimization
- T = 3 Hours
- All solutions were better than existing offsets at *p* = 5%
- Over 75% of solutions were better than existing offsets at *p* = 1%
- Not viable beneath *p* = 1%



(a)

Online Optimization
- T = 15 Minutes
- All solutions were better than existing offsets at p = 50%
- Over 75% of solutions better than existing offsets at *p* = 10% and *p* = 5%
- Not viable beneath *p* = 5%

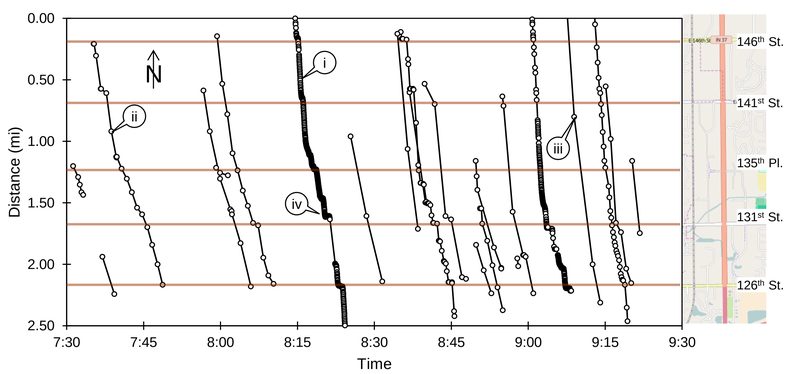


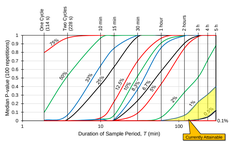
(b)

EXAMPLE REAL-WORLD CONNECTED VEHICLE TRAJECTORY DATA

Southbound, SR 37, Fishers, IN

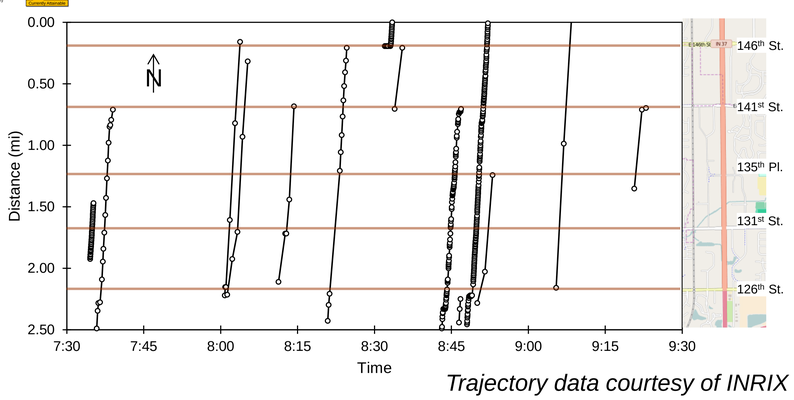
p = 0.8%





Northbound, SR 37, Fishers, IN

p = 0.6%



Trajectory data courtesy of INRIX